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Assessing the Significance of Rate and Time Pulse Spraying in Top Spray Granulation of Urea Fertilizer Using Taguchi Method

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Abstract. Studies in urea granulation process using Top Spray Fluidized Bed Granulator (TSFBG) is still limited and requires in-depth research about the effectiveness and influence of droplets to the formation of urea granule (UG). Rate and time interval of spraying technique (Pulse) significantly influence the physical properties of urea granules. Cassava starch dissolves in water was selected as the binder released at various time interval to observe impact of spray droplet on UG size formation. Using Taguchi Method, the study had identified three leading factors contributed to the formation of droplet size namely volume of binder (VOB), time pulse of spraying (TPS) and spraying rate (SR). These factors were then evaluated in terms of the influence on response as signal-to-noise analysis (S/N ratios) from Taguchi to validate UG size in range 2 mm to 4 mm from screening process with respect to the actual experimental data. These results were useful for future experiment reference to determine pressure drop and surface contact during interaction between droplet and urea powder particles using TSFBG to obtain uniform UG size and smooth surface layer with reasonable hardness.

Introduction

Top Spray Fluidizied Bed Granulator (TSFBG) is a well-known granulation technique used commercially in fertilizer industry [1]. Nevertheless, there is still lack of information regarding the correlation of process factors to the formation of urea granule (UG) size corresponding to slow release concept when interacts with soil capillary in paddy field. Physical size would enhance slow release activity compared to commercial UG size which is diameter currently smaller at below than 2 mm. There are a few certain process factors (parameters) that really contribute to the production of UG size in range (2 to 4) mm. Thus, this research is trying to figure out the correlation between three significant identified factors, namely *spraying rate* (SR), *time pulse of spraying* (TPS) or liquid injection interval and *volume of binder* (VOB) with the size of UG. Taguchi method was used as a soft methodology to identify three factors as screening and followed by experimental to verify the UG features from physical characterization. These factors were influenced by presence of liquid binder used in wet granulation activity such as stated in the following methodology of experiment.

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Methodology

Here, starch from cassava was selected and the consumption volume was corresponds to the factors SR, TPS and VOB. The spraying was done in stages as ratio 1 : 2, whereby 1 was represented for binder and 2 for seeding urea powder at different parameter and condition, the optimum liquid presence in granulation chamber capable to reduce the trace of over wet particles caused by high humidity in granulation chamber at 80°C. The convergence process has been described in previous studies [3] but less focus about effects of these parameters on droplets and UG sizes involving starch as a binder. At critical condition, the attrition of granules could be occurred at temperature 80°C with hyper kinetic motion causes the granule deforms back to powder phase. This situation would be avoided when the equilibrium moisture level controlled by optimum droplets distribution from the liquid spray [4] in presence of the appropriate SR, TPS and VOB.

Liquid binder was prepared as ratio consist of Starch (S): Urea Powder (UP) : Water (W) in percentage of W/W. About 3 grams of starch and 50 grams of urea powder were added into 47 grams of distillate water. The mixture was stirred and heated at 325 RPM and 60°C respectively using a mechanical stirrer hot plate. After 30 minutes, the binder solution transferred via a silicon tube connected to the top spray nozzle inside the granulation chamber. The binder was delivered and controlled by the peristalsis pump and compressed air at a pre-determined pulse rate (time interval injection) at constant pressure 0.8 bar before reaching the nozzle.

Results and Discussion

UG size was measured using mechanical sieve and hardness test Rockwell (Newton) respectively according to several parameter readings such as stated in the following table. The screening was done using software Taguchi method from Qualitek -4 versions. Table 1 shows the correlation of measured factors to the UG size. The experiment was done in 4 stages based on volume and flow rate of the liquid binder sprayed by time interval. The readings were preliminary obtained using One-Factor-at-a-Time (OFAT) screening from 10 ml to 50 ml liquid binder used in 100 grams of urea powder as seeding substrate during granulation process. Beyond than 50 ml, the moist level in granulation chamber was high and causing over wet condition presence with caking problem at the bottom port. VOB of 25 ml and 50 ml were injected by top spray gradually. Each VOB volume was repeated at different SR and TPS. By increasing distribution of binder droplets and spraying rate were contributed high impacts to the UG production compared to time pulse. It was affected by great opportunity of fluidized urea powder interacting with droplets in the formation of UG at circulating condition [7-9], supported by viscous and capillary forces from the binder itself at sufficient air inlet with the appropriate granulation temperature to enhance the micro-kinetics performance from binder injection, particles collision and optimum wetting process in continuous agglomeration for 1 hour operation [10,11].

Fig. 1 shows the SN response graph for granule size of parameter A, B and C. It was observed that SN ratio was found to decrease a little with the increase of parameter A from Level 1 to Level 2. An increase of VOB contributed excessive moist level in granulation chamber, thus, granule has deformed to powder phase, then, VOB was less significant than SR and TPS. Meanwhile, the mean SN ratio increases with parameter B whenever SR increase and enhance the chance of nucleation to agglomerate actively between powders and droplets at optimum moist level and constant temperature. The mean SN ratio goes up for parameter C with the increasing from Level 1 to Level 2 while TPS allows the agglomeration occurs slowly and gradually without over wetting condition if continuous spraying happened.

Table 1 The listed parameters used during top spray agglomeration process.

Exp.	Volume, A (ml)	Spraying rate, B (ml/min)	Time pulse, C (min)	Granule size [mm]			**SN ratio (dB)**
				1st trial	2nd trial	3rd trial	
1	25 (level 1)	5 (level 1)	1 (level 1)	1.35	2.35	2.25	5.098
2	25 (level 1)	10 (level 2)	2 (level 2)	2.30	2.70	2.55	7.958
3	50 (level 2)	5 (level 1)	2 (level 2)	1.65	2.10	2.43	5.943
4	50 (level 2)	10 (level 2)	1 (level 1)	1.85	3.00	2.68	7.427

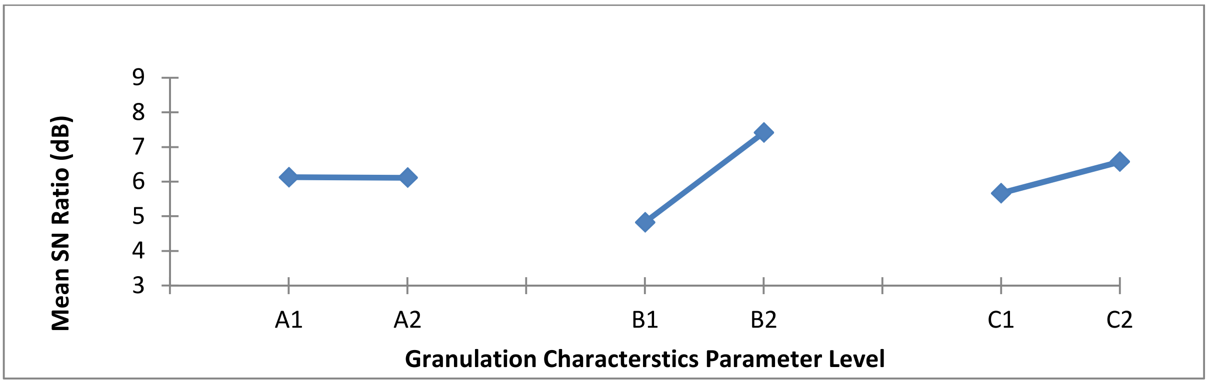

Fig. 1 SN ratio graph for UG size.

Table 2 shows the results of analysis of variance (ANOVA) for UG size. The time pulse is the most significant parameter for UG size. Thus, the contribution orders of parameters are spraying rate, time pulse and volume. The optimal parameters for UG size are volume at level 1, spraying rate at level 2 and time pulse at level 2. Meanwhile the following Fig. 2, indicated the actual UG's images were captured using optical digital microscope (Olympus DSX 100) and digital camera at ordinary shot to distinguish end product on surface mechanism after nucleation completed to form granules.

Table 2 Results of the ANOVA for UG size.

Parameters	Contribution (P, %)	Rank
Volume	0.002	3
Spraying rate	89.06	1
Time pulse	10.935	2
Error	0.003	
Total	100	

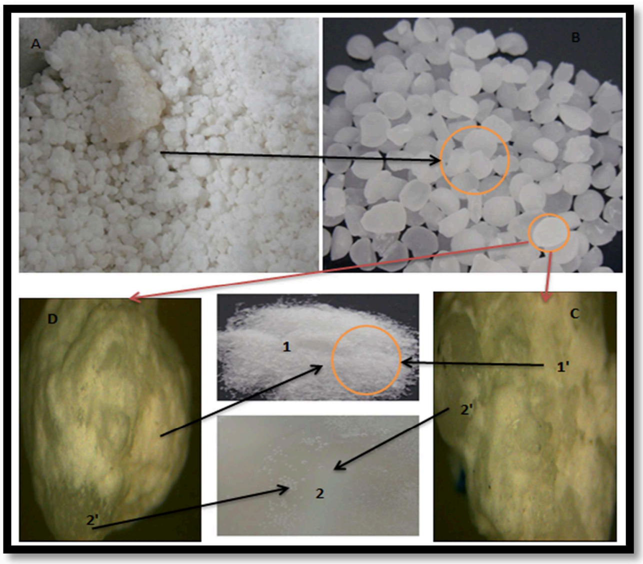

Fig. 2 Stage of the urea granule images captured by digital microscope.

From fine powder, the agglomerated granules were remarked in Fig. 2 as A and B, while C and D were the granules at zooming state to observe an actual mechanism whereby urea powder 1 topping on binder droplet 2, and this was occurred during nucleation and proven that droplet size was bigger than urea particle, while 1’ and 2’ were the images differentiating between droplet and powder surfaces overlapping as granules.

Conclusion

Taguchi method was proven effective to determine the significance of rate and time pulse influences on UG size formation at minimum and maximum levels. According to Table 1 the optimum parameters to form UG size (2.0 – 3.0) mm are 25 ml, 10 ml/min and 2 minutes for VOB, SR and TPS, respectively. These parameters were repeated experimentally to verify the actual UG size obtained at final granulation process and the sizes were close to the expected diameter sizes shown by Taguchi. The obtained information was useful to be referred further during investigation of UG hardness and surface contact studies to identify porous texture and inconsistencies of UG size when the parameters increased gradually [10]. These physical properties revealed the most dominant factor contributed on UG size namely SR to control the spraying angle and enhance the size as well as hardness of UG [11]. According to Taguchi, SR, TPS and VOB were contributed better to UG size at maximum level because of bigger droplets may enhance the opportunity of nucleation during agglomeration process openly gave more chances for size-enlargement to occur [12]. Thus, these three factors SR, TPS and VOB were absolutely important to ensure the obtaining UG size achievable at optimal condition.

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